Atomic Parity Nonconservation in Stable Yb Isotopes

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The weak interaction, best known for its role in nuclear beta decay, also plays a minor role in the electronic structure of atoms. Atomic structure is dominated by the electromagnetic interaction, which conserves parity (mirror reflection symmetry), whereas the weak interaction does not. Measurement of parity nonconserving (PNC) effects in atoms allows one to observe the weak interaction in a system dominated by the electromagnetic interaction. The study of atomic PNC, which is due to the weak neutral current (Z-exchange), complements the study of nuclear beta decay, which results from the weak charged current (W-exchange).

The $(6s^2)^1S_0 \rightarrow (6s5d)^3D_1$ transition in atomic Yb is a promising system for the study of PNC*. The E1 transition amplitude is strictly forbidden by the parity selection rule, while the M1 amplitude is highly suppressed.The application of an external electric field mixes even and odd parity states, giving rise to a Stark-induced amplitude ($E1_{st}$). The weak interaction also mixes even and odd parity states, giving rise to a parity nonconserving amplitude ($E1_{PNC}$). In order to measure a very small $E1_{PNC}$, one observes the interference between the much larger $E1_{st}$ and $E1_{PNC}$, as one excites this forbidden transition with intense laser light. The parity violating effect in Yb is expected to be very large, due to the near degeneracy of two states of nominal opposite parity .

Precise measurements of PNC in single isotopes of Cs[‡] and Tl[‡‡], when combined with atomic structure calculations, have led to a determination of the weak mixing angle ($\sin^2\theta_W$), rivaling those obtained from high energy physics experiments. Comparing PNC effects in several isotopes of Yb may allow us to extract information about the weak interaction independent of the atomic structure. The PNC effect for a given isotope also depends on the distribution of neutrons within the nucleus, a nuclear property not readily accessible by other means. In addition, comparison of PNC effects in the different hyperfine components of the two odd A isotopes of Yb allows a determination of the nuclear anapole moment.

In the past year we have made an absolute measurement of the Stark-induced transition amplitude of the $(6s^2)^1S_0 \rightarrow (6s5d)^3D_1$ transition at 408 nm. Atomic beam strength and fluorescence detection efficiency are calibrated simultaneously using the $(6s^2)^1S_0 \rightarrow (6s6p)^3P_1$ transition at 556 nm. Work is underway to measure the M1 transition amplitude by interference with $E1_{st}$.

Footnotes and References

* D. DeMille, Phys. Rev. Lett. **74**, 4165(1995).

‡ C.S.Wood, *et al.* Science **271**, 1759 (1997).

‡‡ P.A. Vetter, *et al.*,Phys. Rev. Lett. 74, 2658 (1995).

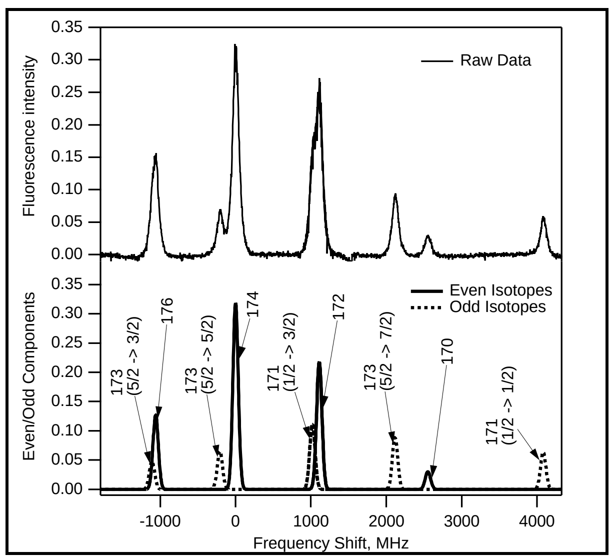

Fig. 1. (Top) Fluorescence signal from the forbidden M1 transition in ytterbium in a 45 kV/cm electric field. (Bottom) Identification of the even isotopes and the hyperfine components of odd isotopes (F-> F′).